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A review on the micro energy harvester in Structural Health Monitoring (SHM) of biocomposite material for Vertical Axis Wind Turbine (VAWT) system: A Malaysia perspective

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ABSTRACT

The usage of wind energy as a form of renewable energy is becoming increasingly popular year by year. This technology has been applied widely in several regions in the world and already reached maturity in terms of technology, infrastructure and cost competitiveness. The performance of the wind turbine system depends upon factors such as design, aerodynamic performance and material selection. Thus, Structural Health Monitoring (SHM) has become crucial in evaluating the performance of wind turbine in real time. Furthermore, the application of smart material in SHM can be utilized as micro energy harvester as well. Nonetheless, the application of SHM in Malaysia's climate for wind turbine is still premature, especially in the approach biocomposites material towards its blade system. Several issues are highlighted in this paper such as Vertical Axis Wind Turbine (VAWT), biocomposites material selection and the issue in the micro energy harvester as well. The issues are discussed and compared with the recent finding in this review. Several recommendations are suggested for future studies in benefiting the Malaysian especially on the application of wind energy to promote better green technology for tomorrow.

Contents

1. Introduction

Green energy or renewable energy becomes important nowadays. The application of renewable energy helps people overcome the continuous decreasing of fuel. Natural resource such as wind, sunlight, rain and geothermal heat are utilized efficiently in energy services such as power generation, heating and transport fuel. The development and research drive for renewable energy has become crucial and continues to rise rapidly since the emergence of the world energy crisis in the 1970s.

In Malaysia, the effort to establish and promote Renewable Energy (RE) has been occurred since 12 years ago. There have been several policies, programmes, incentives and funding which were launched to expedite the development of RE in Malaysia. The policies such as Fifth Fuel Policy 2000 [1], National Bio-fuel Policy 2006 [1–3], National Green Technology Policy 2009 [1,4] and National Renewable Energy Policy 2010 [1,5–7]. In National RE policy 2010, Malaysia had listed several objectives to be achieved and expected to give huge impact by the year 2020.

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Five objectives under National RE Policy 2010 include [6]:

(1) To increase RE contribution in the national power generation mix.
(2) To facilitate the growth of the RE industry.
(3) To ensure reasonable RE generation costs.
(4) To conserve the environment for future generation.
(5) To enhance awareness on the role and importance of RE.

The expecting impact on RE in Malaysia as follows [7]:

(1) Minimum MYR 2.1 billion savings of external cost to mitigate CO_2 emissions (total 42 million tonnes avoided from 2011 to 2020, on the basis of MYR 50 per tonne of external cost).
(2) Minimum MYR 19 billion of loan values for RE projects, which will provide local banks with new sources of revenues (at 80% debt financing for RE projects).
(3) Minimum MYR 70 billion of RE business revenues generated from RE power plants operation, which can generate tax income of minimum MYR 1.75 billion to the Government.
(4) 50,000 jobs created to construct, operate and maintain RE power plants (on the basis of 15–30 job per MW).

The outlined plan listed above shows the seriousness of Malaysia in the implementation of RE. The agendas could save the country of nearly MYR 5 billion (US$ 1.32 billion) if the operation manage to utilize just 5% of RE in energy mix operation within five years [1]. The natural resources in Malaysia such as solar and wind will become an important subject in RE.

Globally, wind energy has a big potential in renewable energy. It can supply more than double of the current world electricity consumption ($15{,}000 \times 109$ kWh per year). The supply can achieve from wind energy is from $20{,}000 \times 109 - 50{,}000 \times 109$ kWh per year [1,8]. It depends on several factors such as average wind speed, statistical wind speed distribution, turbulence intensities and the cost of wind turbine systems. Besides that, there are more than 50 countries and 1500 organizations contribute in hardware manufacturer, project development, power generation, finance and consultancy. This huge number makes the enhancements and advancements of the wind energy technology are expedited and well established. Fig. 1 shows data of the comparison of cumulative wind power installed in several countries at 2004, 2010–2012 [8–11]. It shows that China become the champion in wind power generation around the world with cumulative power of 75,324 MW. It followed by The United States 60,007 MW, Germany 31,308 MW, Spain 22,796 MW and India 18,421 MW. The new installation trend in global industry for 2004 and 2012 is reported in Fig. 2. Europe dominates the trend with 4825 MW at 2004 but Asia defeat the trend with 15,510 MW of new installation

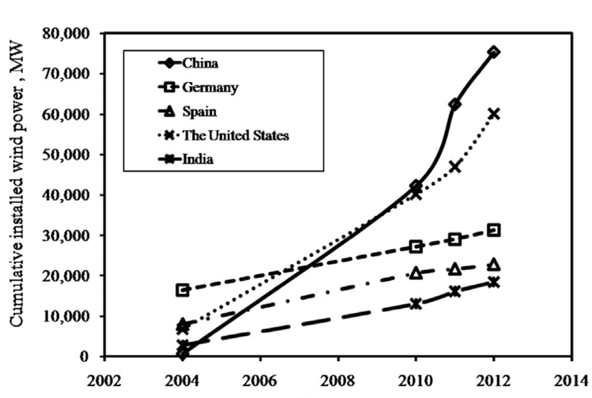

Fig. 1. Total installed wind power for several countries in the world.

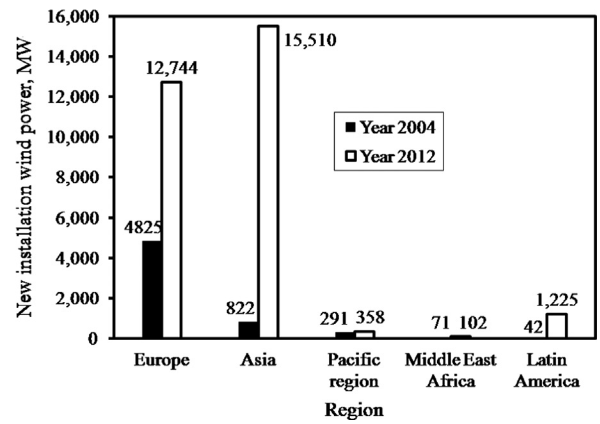

Fig. 2. Trend and new installation of wind power at several regions in the world.

wind power [8–11]. It indicates that Asia is potential region to enhance the technology as it may due to the demand and the appropriate geography factor. Additionally, the reports above obviously show that the technology of wind energy is tremendously evolved and contribute to the development of renewable energy sector.

In Malaysia, the study on wind resource density has already been conducted by several researchers. A ten years study from 1982 to 1991 at 10 different areas in Malaysia suggested that Mersing and Kuala Terengganu have wind power potential with a mean power density of 85.61 W/m^2 and 32.50 W/m^2 respectively [12]. Data for 2008–2009 for Mersing indicates that 2 and 3 m/s is the most frequent wind speed and the highest power density calculated is more than 6 m/s [13]. Furthermore, the annual offshore wind speed in Malaysia is around 1.2–4.1 m/s with east Peninsular Malaysia with the highest in annual vector resultant wind speed of 4.1 m/s [14]. Fig. 3 shows the map of mean power density distribution in Malaysia. In Peninsular Malaysia, huge potential of wind farm location can be observed around northeast, northwest and southeast region. Furthermore, for East Malaysia, the southern region of Sabah is suitable to initiate future wind farm development [14] as well as the northwest coast of Sabah and Sarawak region [4]. In addition, the most potential place in Malaysia is in Terumbu Layang–Layang Island, Sabah which is generating capacity of 150 kW [15]. Besides that, a study on management of green energy for tourism island is conducted at Juara Village, Tioman Island. It reports that the hybrid system of solar and wind energy can generate up to 200 kW solar energy and 40 kW wind energy along with a converter system and a battery as backup to supply the electric energy load demands of all villagers and tourists [16]. Apart from that, another research on evaluation of wind energy potential Malaysia is by Islam et al. [17]. They have analyzed the wind energy potential at Kudat and Labuan by using 2-parameter Weibull distribution. Their results conclude that small-scale wind energy can be generated at the turbine height of 100 m. In addition, Masseran et al. [18] evaluates the characteristic of wind speed and the potential of wind energy for ten wind stations in peninsular Malaysia based on the persistence concept (Fig. 3). The mean wind speed for nine wind stations are Alor Setar 1.74 m/s, Bayan Lepas 1.92 m/s, Chuping 1.03 m/s, Ipoh 1.64 m/s, Cameron Highland 1.90 m/s, Kota Bahru 2.18 m/s, Kuantan 1.55 m/s, Malacca 1.98 m/s, Mersing 2.82 m/s. The research indicates that the stability of wind speed in peninsular Malaysia is quite good. However, in term of energy production, the persistence level at a 4 m/s or 3–5 m/s [4] truncated level are found to be not enough to ensure the sustainable energy production [18]. A study on nine selected coastal sites in Malaysia is conducted to study the feasibility of small wind chargers for remote housing electrification.

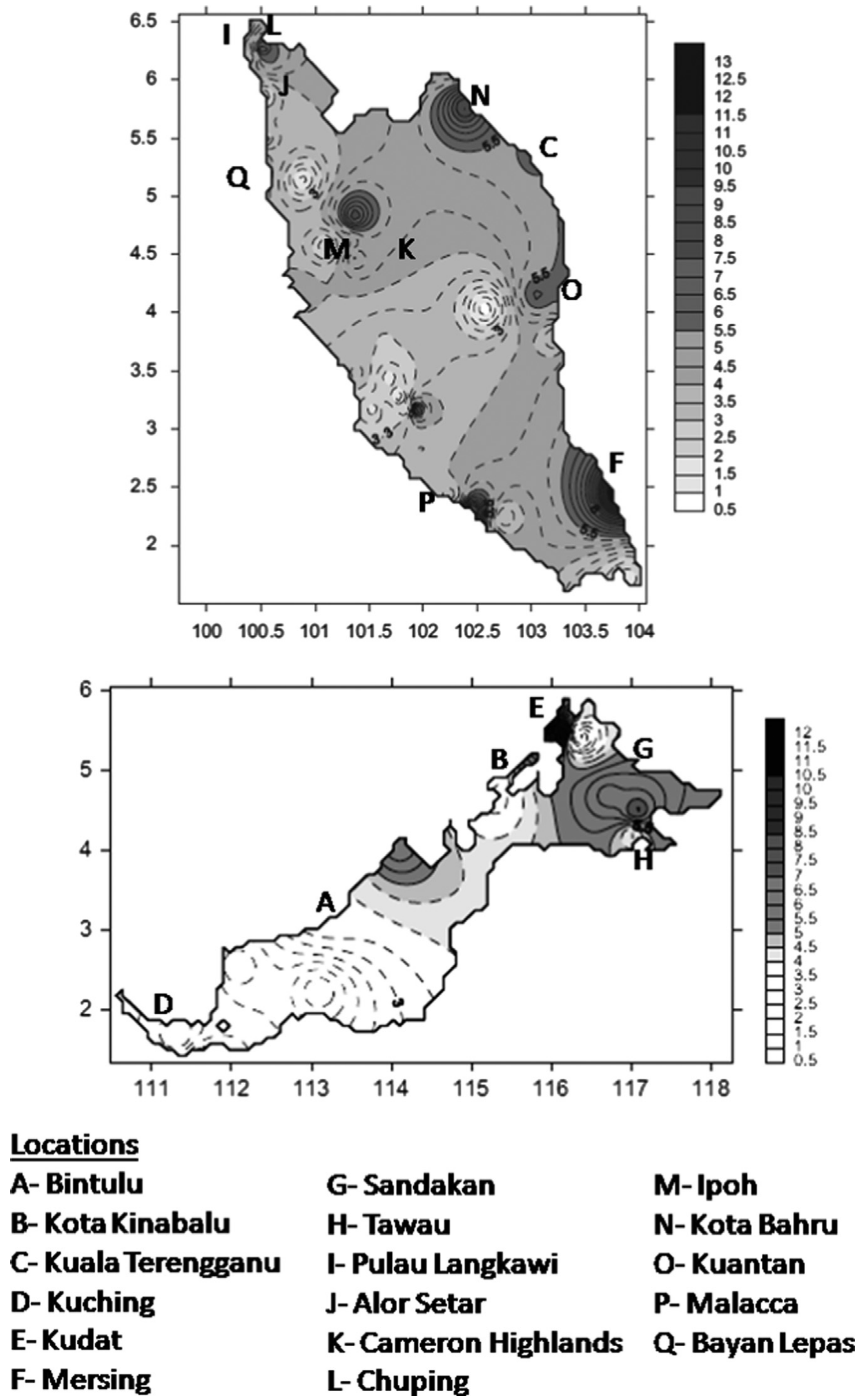

Fig. 3. Map of theoretical mean power in Malaysia [14] and several location of wind flow research [18,19].

The locations of nine coastal sites are exhibited in Fig. 3 and the wind speed distribution is tabulated in Table 1. The study reports that Mersing is the best value for wind charger which is 0.38 USD/kWh with sizing factors of the wind turbine (S_W) and the battery (S_B) for this site are 7.32 and 2.49, respectively [19]. The above data give a clear indication of the potential area of wind farm in Malaysia. The trend of wind energy in Malaysia is still rare due to low resources of wind farm [13]. In addition, as Malaysia is among the highest lightning activities in the world [20], the risk of lightning strikes to the high wind tower may demotivate the growth of wind energy in Malaysia. Most of the rural area in Sabah and Sarawak are applying diesel generator for electricity. Ashourian et al. [16] report that hybrid of wind and solar power will be compromise as the diesel process reaches MYR 2.10/L. On 3rd September 2013, the diesel prize is MYR 2.00/L. Hence, the need to wind energy is become relevant especially for appropriate area which discuss above with proper wind turbine design selection and optimization. The optimum wind turbine design will assist the development of wind energy sector especially to solve the lighting and low wind speed issues.

In Malaysia, two wind turbines (100 kW) were installed in Pulau Perhentian, Terengganu [21]. Moreover, eight units of small wind turbine (5–100 kW) were installed in Sabah and Sarawak by Ministry of Rural and Regional Development for the people [13].

Table 1
Wind speed distribution for the selected sites [19].

Wind speed (m/s)	Bintulu	Kota kinabalu	Kuala Terengganu	Kuching	Kudat	Mersing	Sandakan	Tawau	Pulau Langkawi	Average
(0–1)	1847	567	1462	1987	1474	311	961	2489	1857	1439
(1–2)	3716	3638	3859	3866	2372	1918	2997	3381	3039	3198
(2–3)	2075	3106	1991	1699	1839	3178	2332	1492	1931	2182
(3–4)	856	856	1013	814	1325	1539	1439	941	1218	1111
(4–5)	209	326	305	283	1009	975	278	371	507	474
(5–6)	37	160	86	74	447	533	189	73	154	195
(6–7)	12	57	38	23	181	238	67	9	49	75
(7–8)	4	19	5	8	70	56	28	3	4	22
(8–9)	2	11	1	3	31	9	13	1	1	8
(9–10)	2	7	0	3	8	3	3	0	0	3
(10–11)	0	3	0	0	1	0	3	0	0	1
(11–12)	0	0	0	0	1	0	0	0	0	0
(12–13)	0	0	0	0	1	0	0	0	0	0
(13–14)	0	1	0	0	0	0	0	0	0	0

Chong et al. [24] suggest a vertical axis wind turbine with starting speed 1.8 m/s and integrated with power-augmentation-guide vane (PAGV) [22–25]. The PAGV manage to increase the power generation to 327% compare to normal condition for urban area in Petaling Jaya, Selangor [24]. Generally from above discussion, the sensitivity in optimization, application and wind turbine innovation is imminent and growth positively for the benefit of Malaysian.

2. The Vertical Axis Wind Turbine (VAWT)

Wind turbines can be categorized into two main types. It refers to axial direction of rotor shaft. One is the Horizontal Axis Wind Turbine (HAWT) and the second is the Vertical Axis Wind Turbine (VAWT). HAWT have blades mounted radially from the rotor. Modern types usually have two or three blades and are generally used for large scale grid connected electrical power generation. VAWT is not as common and has only recently been used for large scale electricity generation. The analysis and research on both types of wind turbine are being rigorously tested and improved [8]. Several studies showed that the application of VAWT has more advantages compared to HAWT [26–29]. A comparison between VAWT and HAWT is presented in Table 2 [27].VAWT does not have to be orientated into wind direction. Besides that, it needs no tower hence reducing the capital cost. In fact, the generator is mounted at ground level for easy access [30–32]. Additionally, recent studies show that VAWT can be installed much closer to each other compared to HAWT, so that the power density per square meter could be considerably higher than for the configurations used presently [28]. For above reasons, there is now a necessity to employ VAWT in wind energy application.

The study on VAWT configuration has already conducted and established. There are several configurations listed such as Darrieus rotor – egg beater shaped (Fig. 4), Darrieus rotor – VGOT (Fig. 5), Darrieus rotor – straight bladed (Fig. 6), Darrieus–Masgrowe, Twisted three bladed Darrieus rotor, Crossflex, Savonius rotor (Fig. 7), Combined Savonius and Darrieus rotor, Two leaf semi rotary, Sistan wind mill and Zephyr turbine [26]. In term of manufacturing process and fabrication cost, Darrieus rotor-straight blade or giromill showed reliable configuration. The two blades of giromill generally named as H-rotor [33,34]. Hence, deep consideration and review will be conducted especially in Darrieus rotor-straight blade. The study of VAWT performance is focussing on torque [23,27,35–37], power [23,27,35,36,38] and rotational speed [23]. Several factors influencing the VAWT performance are discussed such as structural integrity, fluid flow around the blade, and wind turbine design. The efforts were conducted in simulation and experimental method and the VAWT performance was improved.

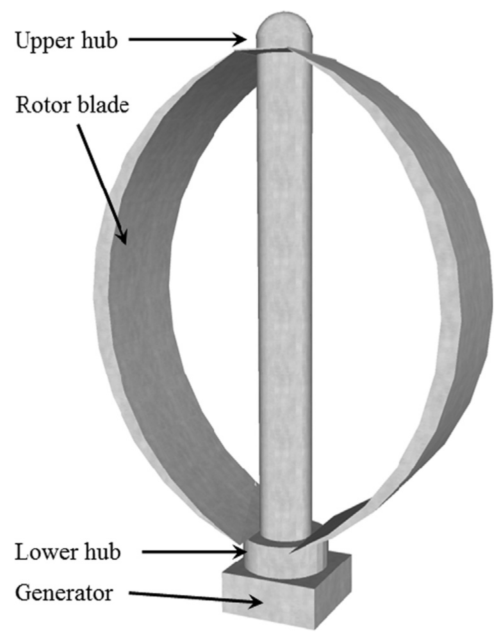

Fig. 4. Darrieus rotor – egg beater shaped [26].

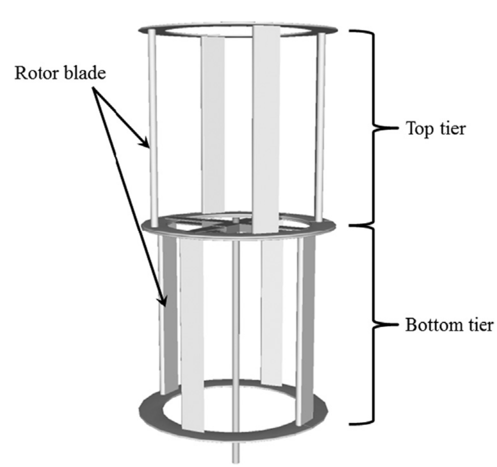

Fig. 5. Darrieus rotor – VGOT [26].

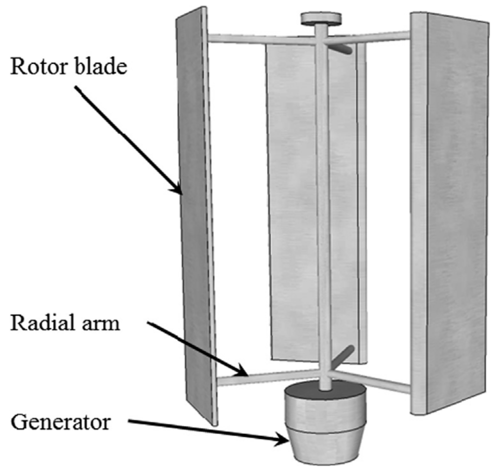

Fig. 6. Darrieus rotor – straight bladed [26].

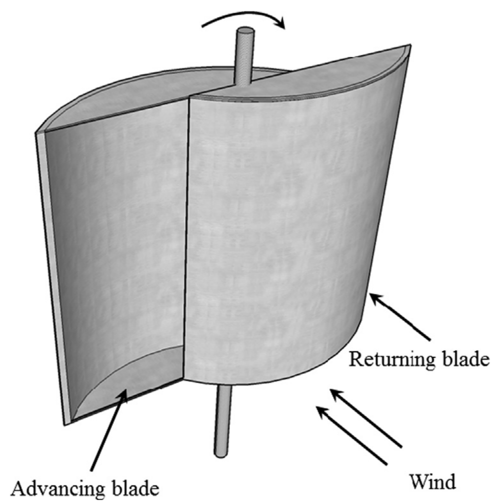

Fig. 7. Savanius rotor [26].

In design analysis, the design configuration may consider combination of several existing VAWT types [36]. The new design of the Darrieus and Savonius combined rotor is proposed and analyzed. The starting torque shows an improvement. Besides that, a comparison was done among existing standard airfoil shape [27]. From 20 designs suggested and run in computational analysis, H-rotor Darrieus turbine using S-1046 type of airfoil appears to be very promising for wind energy generation, particularly in urban areas. Greenblatt et al. [38] proposed plasma actuator in controlling flow separation hence increasing the power generated about 38% in percentage. The selection between fixed and variable pitch blades were studied as well. The result shows that variable pitch blades managed to overcome the starting torque issues associated with VAWTs.

Besides, the additional accessory may help in improving the amount of power generated. The guide vane at the outer devices of VAWT system may act as in the Bernoulli principle. The reductions in air pressure make the air flowing into the tunnel at higher velocity compare to the outer velocity. It improves the rotational speed and starting behavior performance [22–25,39].

The experimental output was also supported and enhanced with simulation analysis. The research on vortex simulation, dynamic stall and height-to-diameter ratio shows better understanding and explanation to the aerodynamic problem in the experiment [40–43]. The selection of codes in computational fluid dynamics analysis were also optimized and improved in the simulation study. Hence, an accurate result could be projected

Table 2
Comparison between VAWT and HAWT [27].

	Vertical Axis Wind Turbine (VAWT)	Horizontal Axis Wind Turbine (HAWT)
Tower sway	Small	Large
Yaw mechanism	No	Yes
Self starting	No	Yes
Overall formation	Simple	Complex
Generator location	On ground	Not On ground
Height from ground	Small	Large
Blade's operation space	Small	Large
Noise produced	Less	Relatively high
Wind direction	Independent	Dependent
Obstruction for birds	Less	High
Ideal efficiency	More than 70%	50–60%

[44]. An analysis on structural integrity was conducted as well. It is study on the effect of faulty blades on the torque and power output. It shows that the torque and power could decrease as the number of missing blades increases [35].

From economic point of view, a study showed that the improvement in aerodynamic design could benefit about 6 cent per each kW/h generated by the designed VAWT [45]. The summary of the above discussion is presented in Table 3. Both simulation and experimental methods were conducted to improve the technology of VAWT especially for RE field. The design analysis seems to have reached maturity. Furthermore, the researchers give very good attention on the parameters involved such as aerodynamics performance and fluid flow analysis. However, there are still research opportunities in optimizing blade design at several factors such as span length, chord length, manufacture ability and aerodynamic shape. Further analysis can be conducted as well to study which factors are most influencing in the VAWT performance. Besides that, the studies on the structural integrity need to be explored further. The issues highlighted in structural integrity such as structure critical point, blade vibration utilization, effect of dynamics of wind flow in a very short period, health monitoring system and material selection.

3. Material of VAWT

On the other hand, the fabrication of turbine blades has become an important issue as well. Composite materials start to replace the applications of metal. Glass fibers are the most widely used to reinforce plastics due to their low cost and fairly good mechanical properties. However, these fibers have serious drawbacks as indicated in Table 4. The use of biocomposites fiber as a reinforcement in Fiber-Reinforced Plastics (FRP) to replace synthetic fibers such as glass is receiving serious attention. This is due to it's advantages such as renewability, low density, and high specific strength. Recent studies have explored the development of biodegradable composite materials using natural fibers such as flax [46,47], bamboo [48], pineapple [49], jute [50,51], kenaf [51–54] as a reinforcement for biodegradable plastics. These studies have examined molding conditions, and interfacial bonding [54] and show positive result. Study on several natural fibers mechanical properties such as tensile strengths, flexural strengths and Charpy impact also shows comparable results to glass fibers [51].

The application of biocomposites fiber is wide. Aerospace, automotive, building, construction and RE are the potential area of application. The potential in automotive industry is convincing [55]. A few part parts can be replaced to biocomposites fiber such as bumper beam and dashboard. A study reports that hybrid kenaf/fiber glass is potential to replace the existing glass mat thermoplastic product [56]. In addition, an extensive study is needed especially on manufacturing processes and commercialization processes at a very

Table 3
Summarize of research conducted in Darrieus rotor-straight blade of VAWT.

No.	Author	Performance parameter	Design parameter	Improvement
1	Davood Saeidi, Ahmad Sedaghat, Pourya Alamdari, Ali Akbar Alemrajabi [45]	Aerodynamic design and economical evaluation	Aerodynamic performance, Power production	The evaluation shows a profit of 6 cent per each kW/h generated power by the designed VAWT.
2	Kyoo-seon Park Taimoor Asim Rakesh Mishra [35]	The torque and power outputs from the VAWT	Blade health	As the number of missing blades increases, the torque and power outputs from the VAWT decrease
3	M.H. Mohamed [27]	To maximize output torque coefficient and output power coefficient (efficiency)	Aerodynamic investigation 1. Airfoil design 2. Mutual interaction between blades (solidity effect)	The optimal configuration of H-rotor Darrieus turbine involving S-1046 appears to be very promising for wind energy generation, in particular in urban areas.
4	David Greenblatt, Magen Schulman, Amos Ben-Harav [38]	Turbine power	1. Dynamic flow Separation control using plasma actuators 2. Viability of up-scaling the turbine 3. Baseline turbine and the effect of slip-rings	1. Turbine power of up to 38% were measured. 2. Up-scaling the turbine by a factor of 5 and 10
5	Feng-Zhu Tai, Ki-Weon Kang, Mi-Hye Jang, Young-Jin Woo, Jang-Ho Lee [44]	LDWT code of Darrieus half egg beater shape	1. Tip speed ratio (TSR) 2. Reynolds number	LDWT codes show better match with test data in the higher TSR region than DART code, previously researched by Sandia National Laboratory
6	W.T. Chong, A. Fazlizan, S.C. Poh, K.C. Pan, H.W. Ping [22]	Starting behavior and rotational speed	A novel power-augmentation-guide-vane (PAGV)	Power-augmentation-guide-vane (PAGV)increased the speed of the high altitude freestream wind for optimum wind energy extraction. Hence increased the rotational speed
7	Jna. Gavald, J. Massons, F. Diaz [36]	Starting torque and power coefficient	New design	New design of the Darrieus and Savonius combined rotor is proposed and analyzed.
8	1. D. Vandenberghe, E. Dick [42] 2. Islam, M., Amin, M.R., Ting, D.S.K., Fartaj, A. [41] 3. Sukanta, Roy., Agnimitra, Biswas., Rajat, Gupta. [40]	Comparison between experimental and numerical analysis	1. Vortex simulation of the wake and the modeling of dynamic stall [23,24] 2. Power coefficient (Cp) at different height-to-diameter (H/D) ratios [24]	Carried out a detailed aerodynamic study of this type of configuration. Closed comparison between experimental and numerical analysis
9	Takao, M., Kuma, H., Maeda, T., Kamada, Y., Oki, M., Minoda, A., [39]	Aerodynamic performance	Power coefficient	Performance parameters improved by addition of guide vane row around the turbine. Power coefficient is 0.215, which is 1.8 times higher than that of the original turbine without any guide [39]
10	Chong, W.T, Poh, S.C, Fazlizan, A. Pan, K.C [23]	Rotational speed, torque output and power output	Omni-directional guide vane	Omni-directional guide vane increases the rotational speed to two times better from the original. Increase torque output by 206% for tip speed ratio of 0.4
11	P. Stein, M.-C. Hsu, Y. Bazilevs, K. Beucke [43]	Aerodynamic performance	Comparison data	Preliminary aerodynamics simulation of a newly constructed VAWT model in 3D under realistic wind conditions and rotation speed is presented
12	M. Islam, D.S.K. Ting, A. Fartaj [37]	Starting torque	Variable blades	Variable pitch blades have the potential to overcome the starting torque issues associated with VAWTs
13	Chong, W.T., Naghavi, M.S., Poh, S.C., Mahlia, T.M.I., Pan, K.C. [24]	Estimated annual energy saving	A novel power-augmentation-guide-vane (PAGV)	Estimation energy saving for wind mill system with the PAGV and an H-rotor VAWT mounted on the top of a 220 m high building is 195.2 MW h/year
14	Chong, W.T., Pan, K.C., Poh, S.C., Fazlizan, A., Oon, C.S., Badarudin, A., Nik-Ghazali, N.	Rotational speed, power output, rotor torque	A novel power-augmentation-guide-vane (PAGV)	The power output increment of the rotor is 5.8 times, the wind rotor rotational speed is increased by 75.16% and simulation study on the rotor torque is increased by 2.88 times with the PAGV
15	John O. Dabiri [28]	Power density	Counter rotating vertical-axis wind turbine arrays	It increase the power density compare to HAWT and capable to alleviate many of the practical challenges associated with large HAWTs, such as the cost and logistics of their manufacture, transportation and installation

specific field such as construction and RE [57,58]. Hence, a focus on manufacturing and optimization process of turbine blades should be give full attention.

4. Micro energy harvester

In order to monitor the sustainability of each component in VAWT, a proper method should be used to monitor the turbine blade and overall system before the operation as well as during the operation of VAWT. In this situation, the application of Structural Health Monitoring (SHM) is very crucial. SHM is a method that aims to identify the health of an engineered system throughout its lifecycle [59]. By using SHM, designers enable to reduce the weight of rotors and drive trains by replacing conservative design assumptions with automatic state awareness and control measures. Furthermore, manufacturers could use health information about loads and the damage correlated with these loads to improve wind turbine designs, manufacturing and quality control processes, and shipping and installation methods [60].

There are several methods in detecting damage or failure in the blade structure. There are techniques such as Acoustic Emission,

Table 4
Comparison between natural and glass fibers.

	Natural fibers	Glass fibers
Density	Low	Twice that of natural fibers
Cost	Low	Low, but higher than NF
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	Wide
CO_2 neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegradable	Not biodegradable

Ultrasonic, Fiber Optic, Laser Doppler Vibrometer and Thermal Imaging [60]. Besides that, there is a new smart material called piezoelectric which offers better technology by not only detecting the damage but acting as an actuator and harvesting electricity as well [61,62]. In this system, the sensor will react if several situations occurred such as curvature of structure, strain state in the sensors, damage in the structure and failure mode of structure by buckling [63]. The piezoelectric sensor act as good as SHM as it offer low in weight, low cost compare to other devices and easy to install [64].

The application of piezoelectric as enhancement of VAWT in energy harvester could become new challenge. As VAWT plays the main role as main energy collector, piezoelectric can act as a micro energy harvester. This technology is focused on the alternatives of the conventional battery. It will be based on mechanical vibration, mechanical stress and strain, thermal energy from furnace, heaters and friction sources, sun light or room light, human body, chemical or biological sources, which can generate mW or μW level power [65]. In VAWT, mechanical vibration is the effect factor to generating power in piezoelectric. Flynn and Sander [66] imposed fundamental limitations on piezoelectricof PZT (lead zirconate titanate) material type and indicated that mechanical stress limit is the effective constraint in typical PZT materials. Their report stated that a mechanical stress-limited work cycle was 330 W/cm^{3}at 100 kHz for PZT-5H. On the other hands, studies on different types of piezoelectric material were conducted in Inman's group such as monolithic piezoelectric ceramic (PZT), bimorph Quick Pack (QP) actuator and micro fiber composite (MFC) [67–71]. The papers report on the efficiency of MFC and PZT and the capacity to recharge a discharge battery on the three types of material. Furthermore, PZT piezoelectric cantilever was proposed in a micro machined Si proof mass in a low frequency vibration application [72]. Beside, the frequency flexibility and power output can be improved via an array of power generator based on thick-film piezoelectric cantilever [73]. Most of the researches are focusing on vibration cantilever beam. The study on VAWT needs to be explored and experimentally validated with the current situation on Malaysia environment.

5. Conclusion

The need of RE become more significant nowadays due to several issues such as global environment problem, the depleting of fossil fuel thus raise the oil price as well and economic concern. In Malaysia, the growth of heavy industry have promote to pollution rise [74]. Besides that, the demand on electricity for industry and the community will increase as well. In this situation, government already take smart action in promoting, enforcing and enhancing the RE by the policy or act that already launched. However, sufficient amount of funding should be allocated to enhance the technology in solving fundamental problems as well as product design and development [21]. The funding system have to be integrated with proper implementation and monitoring system. Obviously, in Sabah and Sarawak with highest concentration of poor people and lowest electricity coverage are required appropriate RE technology [13]. In some areas, wind resources are sufficient. Even the technologies of various types of VAWT are already established and commercially available in the market. The discussion on aerodynamic design of VAWT which can operate at Malaysia's weather condition is very crucial. It must be commercially ready and tested for the user as well. In addition, with the increasing of diesel price to MYR 2.00/L the application of wind energy should be promoted and employed especially for diesel generator user in respective area.

On the other hands, there are two issues can be highlight in terms of green technology. First, the application of biocomposites fibers or green material in order to avoid and reduce the utilization of synthetics fiber composite. There is still a gap in optimizing the manufacturing process of biocomposite fibers especially in fabricating VAWT. Hence, the mechanical properties need further investigation. Secondly, the enhancement of smart material in SHM technology which perform as a micro energy harvester. The piezoelectric is smart material which can perform as sensor, actuator and energy harvester. The utilization of this technology could bring VAWT a step forward with additional features. However, it needs further analysis and optimization in terms of dual function of the piezoelectric. Several issues can be highlighted here such as efficient electronic circuitry for energy harvesters, the embedded method and critical location in VAWT for optimum signal receiver.

Renewable energy becomes a main topic in global energy field. Combination of green material and smart material in VAWT could gain and bring the wind energy to new era. The application of biocomposites fibers not only preserves the world from non disposal waste but create huge jobs opportunities to rural communities especially in several areas in Malaysia. Furthermore, the application of smart material in VAWT can enhance the technology of wind turbine and create new jobs and develop knowledge for future application. The study of the impact of wind energy on the future and product development should be performed to ensure that it will be very profitable and contribute a lot to the world.

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